reviewed paper

A Smart Home Network for Proactive Users

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1 ABSTRACT

According to the European Strategy Energy Technology (SET) Plan, the resident-user engagement into the national energy strategy is pivotal, as reported by the Challenge 1st: “Active consumer is at the centre of the energy system”. The Italian Ministry of Economic Development and ENEA have entered into a Program Agreement for the execution of the research and development lines of General Interest for the National Electricity System. In particular, as part of the “Development of an integrated model of the Urban Smart District” project. An experimental demonstration of a Smart Home network is being carried out in the Centocelle district of Rome and called “Smart Home Centocelle”.

The project was developed in an informal settlement, which shares a common background with likewise urban settings, such as a lack of public transportation convenience or enjoyable public spaces and average quality housing, whereas people who adhered to the project have a medium-high education level and proved to be sensitive to alternative and more sustainable energy sources.

Our research has examined the deployment progress made so far, gathering and analysing all the information to assess how the project applications could affect various quality-of-life dimensions: safety, health, environmental quality and personal comfort perception, social connectedness and the cost of living, above all.

Keywords: holistic approasch, quality of life, high technologies, proactive users, smart home network

2 CURRENT STATE OF TECHNOLOGY AND RESEARCH IMPROVEMENTS

2.1 Introduction

In the framework of the Electric System Research Program supported by the Ministry of Economic Development, ENEA is carrying out a project for the definition of a replicable model of Smart Homes Network (SHN).

Currently, the Smart Home market and particularly IoT is constantly growing (185 million Euros, + 23% compared to 2015) [1] but, until now, it has been mainly driven by the issue of security, despite technology rapid progress promises to make available more and more features [2].

Moreover, producers, insurance companies, utilities and OTT (Over The Top) have shown great attention to the Smart Home project; for instance, Google with the Nest thermostat or Amazon with Alexa. The entry of such big companies has increased consumers’ confidence in the connected home. [1]

Our project aims to develop a replicable model of SHN,which will be able to monitor energy consumption, the degree of comfort and safety in residential buildings and will then to transmit raw data to a higher level ICT platform which will analyse and aggregate it, providing the user and the community with a series of constructive and valuable feedback which may shed light on their usage patterns and what ought to be improved to increase their energy awareness.

Although the usersare entirely free to choose how and whether to interact with the technology, the feedback they are given can guide them through a path of growth of energy consciousness to cut down on the final energy consumption, both electric and thermal. Besides, thanks to the SHN system, it is feasible to shape innovative housing solutions and to integrate functions in order to reduce final energy consumption providing traditional services, such as safety and security control or assisted living, as well as more personal innovative services.

The system architecture is presented and described in Section 2.2, while the Smart home toolkit is described in Section 2.2.1. Section 3 focuses on the chosenneighboroughoodfrom an architectural point of view, while Section 3.2 deals with user's engagement; lastlty Section 3.2.1 depicts the feedback and services provided. Finally, in section 4 the conclusions are presented. Section 5 is for the references.

2.2 Design of the system architecture

The design of the SHN system is based on specific requirements, which the identified technological solutions are able to provide, namely use of standard and open communication protocols, in addition to wireless devices usage, easy to install and fairly cheap.

The system architecture comprises two different levels: a)building and b)aggregator. Each level is associated with a particular component to which precise functions and services are assigned.

At the single dwelling level (a), the system core is the Energy Box (EB) that collects data from the sensors' network installed at home; this methodhasproved to be valuable to control some devices and it acts like a communication gateway between the smart home and the aggregator. The user can interact with the EB via PC or smartphone through appropriate communication interfaces that allow to control and manage the systems inside the home (web-service, smartphone apps). The upper level, namely the Aggregator, consists of an ICT platform able to collect, aggregate and analyse all the data taken from the home network and to provide the users with a series of constructive feedback. The system itself allows for simple management and remote data viewing.

Both the ICT platform and EB were developed by ENEA research lab in collaboration with Apio [3]. The EB can integrate sensors with different communication protocols (Z_Wave, EnOcean, etc.), it can also implement rules for home management, chart the trends of each device, create apps and additional services to be offered. It is synchronised with the aggregator so that the users can monitor and control their home remotely having the same interface used when connecting to it through the domestic Wi-Fi.

2.2.1 The Smart Home toolkit in detail

These research activities [4] have led to [5] a sensor toolkit for the home energy management, taking into account as benchmark a 6 rooms house of about 100 square meters, equipped with an independent heating system, as shown in Figure 1.

In order to monitor the general building electricity consumption, the project entails the usage of a specific sensor called Energy Meter (EM). Installed directly into the electrical panel of each monitored dwelling, through an amperometric clamp, it makes it viable to measure the electrical energy consumption in real time. Moreover, it is powered by the electrical panel, without any need for other power supply. It was alsoused to monitor the photovoltaic systems' energy production.

Another gadget of the smart sensor toolkit is the smart plug connected to the outlet and used for the measurement and control of the electric load. Monitoring the consumption of homedevices via smart plugs is also useful for the disaggregation of electricity consumption data from the aggregate data provided by eachEM.As far as the measurement of electricloads, it was decided to monitor a more controllable amount of electrical power supplied to home devices such aswashing machines, dishwashers, tumble dryers and water heaters, as they are the key to running Demand/Response services. In addition, continuous loads, such as refrigerators and ovens, have been monitored to facilitate data disaggregation and to unfold usage pattern. Smart plugs installation, however, was quite a challenge, asmodern kitchen appliances are often not easilyaccessible.

In order to monitor theair conditioners split-system energy consumption, especially for summer cooling, a switch was installedin order to measure and controlthe electric switch load.

The smart valves, installed on each radiator, have the task of regulating the room temperature according to the level of comfort chosen by the user. Unlike traditional valves, the new onesare able toindependentlymaintain a constant temperature in each room. This allows using the heating only where and when needed. Furthermore, thanks to the scheduling function implemented at the EB level, it is possible to vary these temperatures according to the time and day of the week for each environment.

The contact sensors detect the opening/closing of doors or windows by sending a changing signal to the wireless network. This sensor can turn off the heating/cooling system in the house when a window is detectedas "open". Furthermore, all this information can be used to turn on burglar control or to enable security strategies if in place.

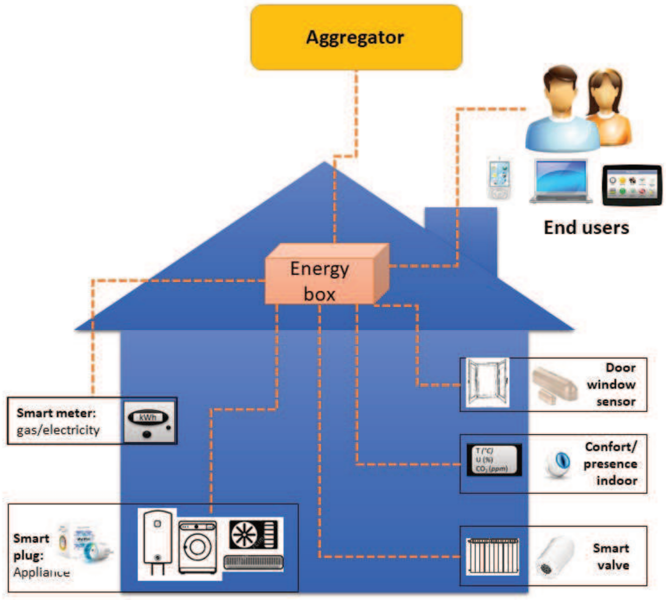

Fig. 1: System architecture.

Eventually, a multi-sensory device was installed, integrating three different functions: motion detection, temperature and light sensor (luminance).

This kind of sensorswas positioned in each room and they can be used for security, intruderdetection, automation and energy management.All the sensors are available on the market and they are wireless, therefore they do not require any wiring during installation.

The described toolkit is being tested in a pilot demonstration carried out in the Centocelle district of Rome, wherethe experimentation was divided into several phases. In order to ensure citizens' involvement, meetings were organized in the district in each phase of the project:

- Project presentation and adherence by filling in the application form;
- A quick energy auditof all the buildings included in the research programme;
- House plan drawings with sensors installed;
- SH toolkits delivery and sensors installation;
- Start of experimentation and instruction manual delivery;
- System operation check and periodical evaluation of results.

3 CENTOCELLE NEIGHBOURHOOD AND USERS' ENGAGEMENT

3.1 Introduction

As above mentioned the smart home project was developed in the Centocelle district, as shown in Fig. 2, in the south-east outskirts of Rome, within the outer motorway belt. The core of this suburb was designed and built during the 20s-30s decade. The actual neighbourhood as it is today is the result of the inclusion of a previous urban sprawl during the decade 60s -70s. Even though is located between via Casilina on the south and via Prenestina on the north, not so far from Rome's city centre, it shares a common background with likewise roman urban settings, such as a lack of public transportation convenience or enjoyable public spaces and an average standard quality housing.As a contrast, people who adhered to the project have a medium-high education level and proved to be sensitive to alternative and more sustainable energy sources. Such peculiarity has made it the eligible venue wherein the simulation is being carried out. Furthermore, the users' enthusiasm is vital to trigger the leap and turning them from a mere user into a promoter of the technology itself, enlarging the perspective from a small scale up to a larger one.

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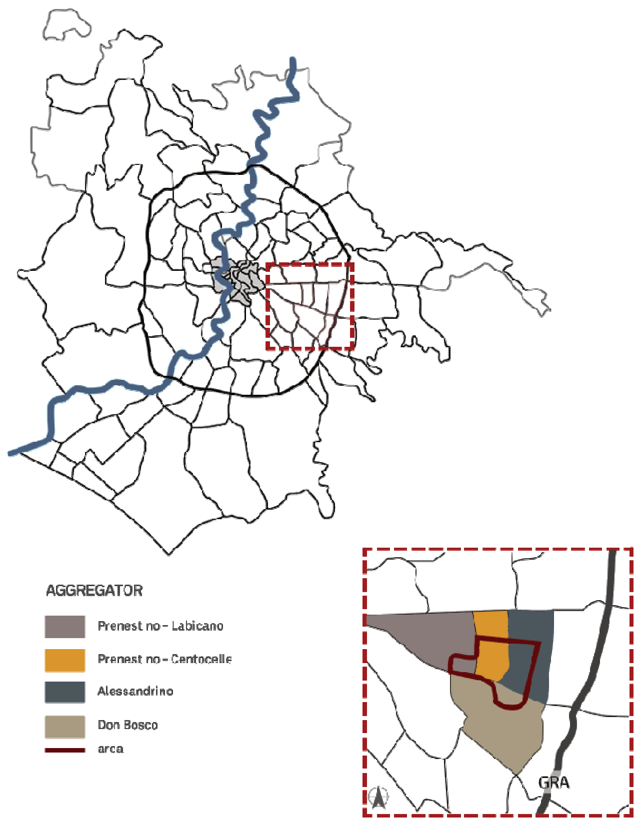

Fig. 2: Rome city map and Centocelle district zoom in.

The issues that this research is aimed to tackle do not stand alone, but are part of a wider context, as a small community is only a single part of a larger city.This project research presents a unique approach to investigating the key factors to build not only a smart homes network but a larger and more complex smart community. Among the project goals are the engagement of people who chose to take an active part in it by arousing their technology awareness.

Community engagement is essential for building a smart city. Smart cities have been depicted so far as safer, friendlier and greener as a result of a combination of a growing human, infrastructure, and entrepreneurial capital[6]. Initiatives in smart cities are intended to promote community and citizen engagement. Research indicates that community and civic engagement is closely related to the development of smart cities[7]. Their long-term benefits have been not only linked to the enhancement of community engagement, but also to the increase in the sense of belonging to a community. Creating local networks of community members fosters a climate where more people are willing to work toward a goal[8].Smart community-based initiatives, like the one being carried out in the Centocelle district, have been intended not only to turn people into more conscious tech-users but to foster social inclusion and deal with local challenges, as they promote the sustainability of provided services[9].

Setting up a smart city involves that people are the building blocks of a thriving community and their participation in itsbottom-up activities shapes the degree of an engaged community and pave the way in taking the next steps toward a more sustainable way of living. If engaged, they can advocate to move the vision forward and make sure their communities are more prepared to withstand climate-related risks in the near future, because people shape the future of a more resilient city made for them to live and flourish in and not a plain city of things, even if smart things.

3.2 Users' engagement

Before the experimentation started, users asked for information about any risks to health and privacy protection. In this regard, it has been clearly specified that the sensors could not pose any health risks as they use a wireless communication protocol created and designed primarily for home automation, whose operating frequency is 868.4 MHz. The use of this band allows the user to have no interference with other systems such as Wi-Fi and Bluetooth, both operating in the 2.4 GHz band (as well as the Zig-Bee protocol).

The Z-Wave standard has a greater ability to cross the walls of buildings compared to the Wi-Fi one and this skill makes transmission safer and more efficient. Besides, the low power, also due to the reduced data flow, ensures that the solution is not dangerous for people health.

As far as the user's privacy, data from homes will be acquired anonymously and then aggregated for the definition of KPIs. Therefore, no user will be able to access any information about each other. The comparison between users will also take place using KPIs. Eventually, the data will be analyzed for statistic purposes and not assigned to third parties. The remote control can only be carried out by the house owner who can choose whether or not to use the devices remote control function such as a smart plug or smart valve, but in no case, the implementation entails the involvement of third parties.

During the first phase of experimentation, thanks to a team of psychologists and sociologists, a survey [10] were conducted to detect the acceptability of the equipment installed in the demonstration by the users involved in the Experimental Group (GS) experimentation and potential users (Control Group, GC), dwelling in the same neighbourhood. To this end, a questionnaire was administered including open-ended and closed-ended questions and standardized questionnaires [12][15][16] used to investigate perceived social support as an aspect that affects the adoption of sustainable behaviours in general and therefore also on the acceptability of the technologies itself.

The results of the survey show that Smart technology is accepted both by those who have benefited from the experimentation and by those who have only imagined fruition.

The GS Family Units have shown enthusiasm, advanced proposals for improvement and even raised criticism based on the direct experience of smart technology. On the other hand, the interlocutors of the Control Group have shown their expectations regarding this technology, based on their current needs. Despite the GS has replied that the technology has not favoured a greater sensitivity towards environmental issues and has not helped to change their habits, from the comparison between the consumption monitored during the experimentation and the consumption of the previous year as detected by the energy bills, an average saving of 8% on electricity consumption was observed, a symptom that, despite not being perceived, the change occurred, not only in the most energy-hungry families.

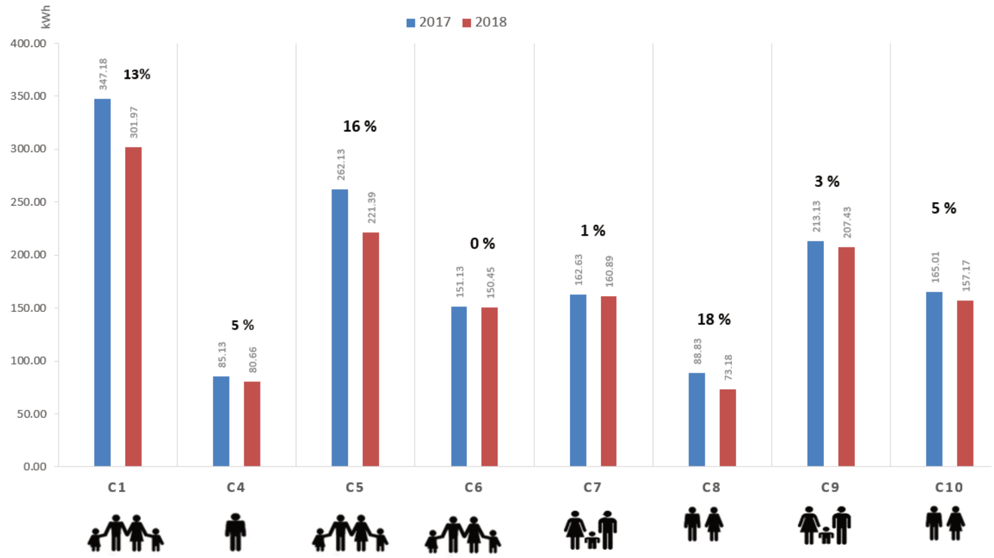

Fig.3: A comparison of monthly average consumptionbefore and after the experimentation

This kind of analysis was useful to identify the most appropriate methodology and type of communication to put energy information across to end users in order to increase their awareness and facilitate the adoption of more energy-efficient behaviours. Greater sensitivity was detected in terms of cost reduction, in fact, energy savings have been quantified in € rather than in KWh. Furthermore, it is quite helpful to improve the pros and cons ofa feedback system (with relative perceptual and cognitive reinforcements) for the daily energy consumption'susageto be modified. To this end, the users were provided with monthly feedback in which previous results are summarisedin comparison with the ones of other participants in the experimentation.

The feedback showed a fairly sensitive improvement,positivelyevaluated. As a result, the userswere given the chance to personalise the domestic environment and additional services, such as smart home, smart

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health and smart wellness, which will encourage greater compliance with smart consumption. They can set up integrated or convergent paid services with other media, generating added value for the provider. Lastly, they will be able to converge with social media and therefore encourage greater integration of the Smart Community.

3.2.1 Users' feedback and services provided

The SHN system main goal is to reduce the energy consumption, by increasing the user'sawareness of their consumption patterns and, at the same time, by ensuring remote control and automation of some features within the home. In addition, the Smart Home infrastructure can enable the home user to demand response services: users can modify their energy demand in response to requests from an Aggregator, receiving a reduction of the energy cost in return.

Although the usersare entirely free to choose how and whether to interact with the technology, the feedback[13] they are given can guide them through a path of growth of energy consciousness to cut down on the final energy consumption, both electric and thermal. The novelty of the project approach is that it startsbyengaging residentsfrom the outset throughout meetup and self-energy audits to design a user-friendly interface and let them get started with a brand-new technology and become more proactive users. In order to familiarise the users with the technology in place, they were given additional services, in terms of home security, assisted living and demand/response control.

Thanks to the responsive data processing the EBis able to manage potential risk events. Technology is the tool to make a city smarter, yet becoming a smart city is not only a goal, but a means to an end: the entire point lies in responding more effectively and dynamically to the needs and desires of residents, especially to the most vulnerable people in our cities: elderly, children and disabled people. The EB for instance already integrates a customised platform that allows the user to check on his vital signs thanks to the use of an eleven sensors toolkit. Since the system shares the same interface of the house energy management console, it is then easier to evaluate the health of those living there. The ability to perform some routine exams in the comfort of your own home can have a strong impact on people's quality of life, as well as reducing costs for both themselves and the healthcare system. In fact, the integration of heterogeneous data is important for decision support, with little impact on the installed equipment and with a consequent reduction in costs and better user acceptability.

The additional services offered to the user are described below:

- security – services that provide home detection or the break-in of the locking systems. The system is able to provide the user or third party specifically enabled a warning notification;
- safety – services that monitor specific environmental parameters (smoke detectors, CO_2, flood sensors, etc.) and detect particular risk situations to prevent injuries or potential pitfalls;
- assisted living - services to support vulnerability to improve quality of life, to help people living better and longer in their own homes, as long as possible[14].

The monitored data are transmitted in real time to the aggregation cloud platform, where the "raw" data are integrated and processed to obtain more information. From 2018 on, two dashboards have been properly implemented to display the acquired data and to provide a different kind of feedback according to the type of recipient:

- a user-friendly interface with constructive feedback on household appliances plus general energy consumption to motivate usersto have more efficient behaviour. Users can do:
    - a comparison with themselves, by monitoring the entire amount of consumed energy and consumptionbreakdown by single appliances.
    - checking their progress over time by contrasting the consumption of the current year with the same of the previous one.

Fig. 4: Aggregator user-friendly interface. The user with themselves.

- a comparison withother users: in this case the energy consumption analysis is carried out by contrasting it with families similar by composition.

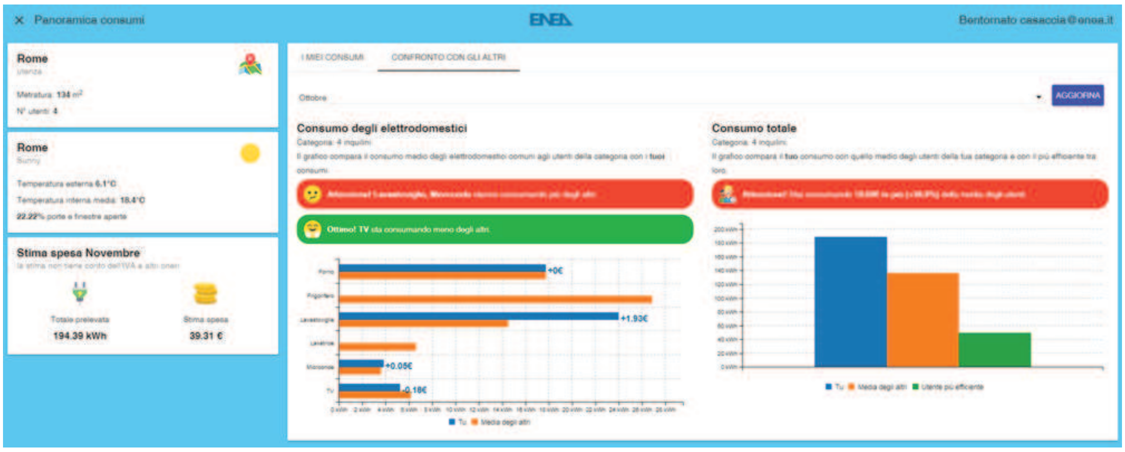

Fig. 5: Aggregator user-friendly interface. The user with others.

4 CONCLUSION

The unfolding of technology and the development of diverse applications demonstrates how it is possible to exploit the data collected from connected objects disclosing their hidden and enormous potential. The integration and processing of data from these devices can offer additional services to the user, which go beyond the simple energy management for which they were thought. Therefore, we can assume that a progressive growth of customised services offered to the users will help themto live better in the comfort of their own home. These services may concern not only security but also, for instance, Assisted Living. Furthermore, future developments will have to take into account the users acceptance of these innovative systems.

By focusing on people collaboration on the project, promoters have shifted the focus from top-down initiatives entrenched in a traditional hierarchy to bottom-up ones in order to expand their creativity; for this reason, the solutions must be innovative and adaptive and will aim to bring the users closer to new technologies.

The participants in the experimentation appeared as users who want to play an active role in the management, even in the design process, in some cases, of smart technology devices. These are users who are familiar with technological equipment and who are inclined to install smart home technology as long as it does not bother but rather responds to the specific needs of individuals and families. The demand for personalization and integration with the domestic environment (smart home) seems to be the clearest request.

Communication as content and modality (sensory, smartphone, web, voice, writing) should be left open to a wide range of possible options, each and every chosen by the user. The frequency of communication is a central factor for which one could consider a modulation of frequencies on different channels.

The survey results made it possible to evaluate any future planning scenarios by referring to the potential and reflections that emerged from the participants. The wills and the qualitative resources that emerged in terms of ideas and proposals for services improvement and technologies adopted, accepted or not and hypothesised as improbable, has allowed us to construct a framework of potential future actions regarding a more personalised, integrative and easy technology also for needs that can be resolved through digital assisted living.

5 REFERENCES

[1] AlmavivA, A. Dexter, L. Chiesa, C. Xie, "Using Infrared Thermography to Visualize the Invisible: Investigating Heat Transfer", in Proceedings of 11th International Conference on Quantitative InfraRed Thermography: Naples, Italy, June 11-14, 2012. Politecnico di Milano, "Internet of things: oltreglioggetti, verso iservizi" : Milan, Italy, April 21, 2017.

[2] S. Aman, Y. Simmhan, V. K. Prasanna, University of Southern California, "Energy Management Systems: State of the Art and Emerging Trends", rivista IEEE Communications Magazin vol. 51, January, pp: 114-119, 2013.

[3] https://www.apio.cc/piattaforma/apio-os

[4] G. D'Agosta, C. Novelli, F. Pieroni, S. Pizzuti, F. Romanello, S. Romano, A. Zanela, "Sviluppo dellemetodologie e implementazionepreliminare di un modello di Smart Homes Network". Research Report RdS/PAR2015/015.

[5] S. Fumagalli, S. Pizzuti, S. Romano, ""Smart Home Network: sviluppo dei servizi di aggregazione e progettazione di un dimostrativo pilota"". Research Report RdS/PAR2016/006.

[6] Kourtit, K.; Nijkamp, P. Smart cities in the innovation age. Innov. Eur. J. Soc. Sci. Res. 2012, 25, 93–95.

[7] Carè, S.; Trotta, A.; Carè, R.; Rizzello, A. Crowdfunding for the development of smart cities. Bus. Horiz. 2008, 61, 501–509.

[8] Bassler, A.; Brasier, K.; Fogel, N.; Taverno, R. Developing Effective Citizen Engagement: A How-to Guide for Community Leaders; Center for Rural Pennsylvania: Harrisburg, PA, USA, 2008.

[9] Lea, R.; Blackstock, M.; Giang, N.; Vogt, D. Smart cities: Engaging users and developers to foster innovation ecosystems. In Proceedings of the ACM International Joint Conference on Pervasive and Ubiquitous Computing, Osaka, Japan, 7–11 September 2015; pp. 1535–1542.

[10] Mind Force Society – Report RdS/PAR2017/045– "Studio sull'accettabilità da parte degli utenti residenziali della strumentazione per la gestione energetica e l'assisted living" F. Orsucci; R. Chiarini, G. Paoloni; A. Mazzeo.

[11] Cook, D.J., J.C. Augusto, V.R. Jakkula (2009), Ambient intelligence: technologies, applications, and opportunities, Pervasive Mobile Comput. 5 (4) 277–298, http://dx.doi.org/10.1016/j.pmcj.2009.04.001.

[12] Donalds Herbourne, C. and A. L. Stewart (1991). The Mos Social Support Survey. Sot. Sci. Med. Vol. 32, No. 6, pp. 705-714, Printed in Great Britain.

[13] Faruqui, A., Sergici, S., & Sharif, A. (2010). The impact of informational feedback on energy consumption—A survey of the experimental evidence. Energy, 35(4), 1598-1608.

[14] Kleinberger, T., Becker, M., Ras, E., Holzinger, A., & Müller, P. (2007). Ambient intelligence in assisted living: enable elderly people to handle future interfaces. In International conference on universal access in human-computer interaction (pp. 103-112). Springer, Berlin, Heidelberg.

[15] Lubben, J. (1988). Assessing social networks among elderly populations. Family & Community Health: The Journal of Health Promotion & Maintenance, 11, 42-52.

[16] Lubben, J., Blozik, E., Gillmann, G., IIiffe, S., von Renteln Kruse, W., Beck, J. C., & Stuck, A. E. (2006). Performance of an abbreviated version of the Lubben Social Network Scale among three European Community–dwelling older adult populations. Gerontologist, 46(4), 503–513.